The Recycling Rate of Atmospheric Moisture Over the Past Two Decades (1988-2008)

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Overview

- Motivation
- Data
- Revisit Previous Studies
- New Results
- Conclusions

Motivation

- **Recycling rate (or residence time) of atmospheric moisture is an important index of climate change.**

- **How does recycling rate change in response to global warming?**

Background

Definition $R = P/W$ (Chahine et al., 1997)

R: recycling rate; P: precipitation; W: column water vapor

$$\Delta R/\overline{R} \approx \Delta P/\overline{P} - \Delta W/\overline{W} \qquad \varepsilon = \frac{\Delta P/\overline{P}}{\Delta W/\overline{W}}$$ (Stephens and Ellis, 2008)

$\Delta R/\overline{R} > 0$ or $\varepsilon > 1$ when $\Delta P/\overline{P} > \Delta W/\overline{W}$

$\Delta R/\overline{R} < 0$ or $\varepsilon < 1$ when $\Delta P/\overline{P} < \Delta W/\overline{W}$

Some model studies suggest $\Delta R/\overline{R} < 0$ **or** $\varepsilon < 1$

A recent observational study (Wentz et al., 2007) suggests

$$\Delta R/\overline{R} > 0 \quad \text{or} \quad \varepsilon > 1$$

Data Sets

- **Precipitation (P)**

  GPCP (V2 and V2.1) 2.5º× 2.5º global monthly precipitation (1988-2008)

  SSM/I (V5) 0.25º× 0.25º oceanic monthly precipitation (1988-2008)

- **Column Water Vapor (W)**

  SSM/I (V5) 0.25º× 0.25º oceanic monthly precipitation (1988-2008)

  AIRS (V5) 1º× 1º global monthly data (2002-2008)

  NVAP 1º× 1º global monthly data (1988-2001)

- **Temperature (AT and SST)**

  NCEP2 2.5º× 2.5º global monthly atmospheric temperature (AT) (1988-2008)

  NOAA 2º× 2º monthly sea surface temperature (SST) (1988-2008)

Revisit Previous Study (Precipitation)

Based on the old version data sets (GPCP V2 and SSM/I V4),

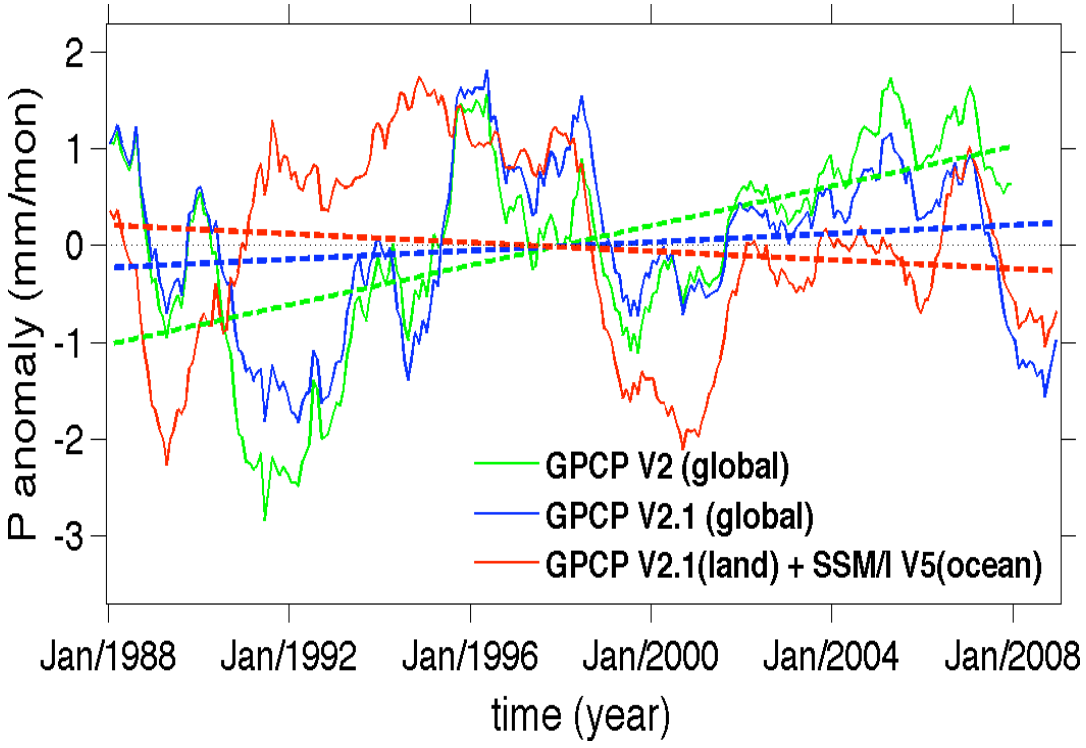
Wentz et al. (2007) got (1988-2006)

$\Delta P/\overline{P}$ (globe) = 1.4±0.5%/decade

$\Delta W/\overline{W}$ (ocean) = 1.2±0.4%/decade

$\Rightarrow \Delta R/\overline{R} \geq 0$ or $\varepsilon \geq 1$

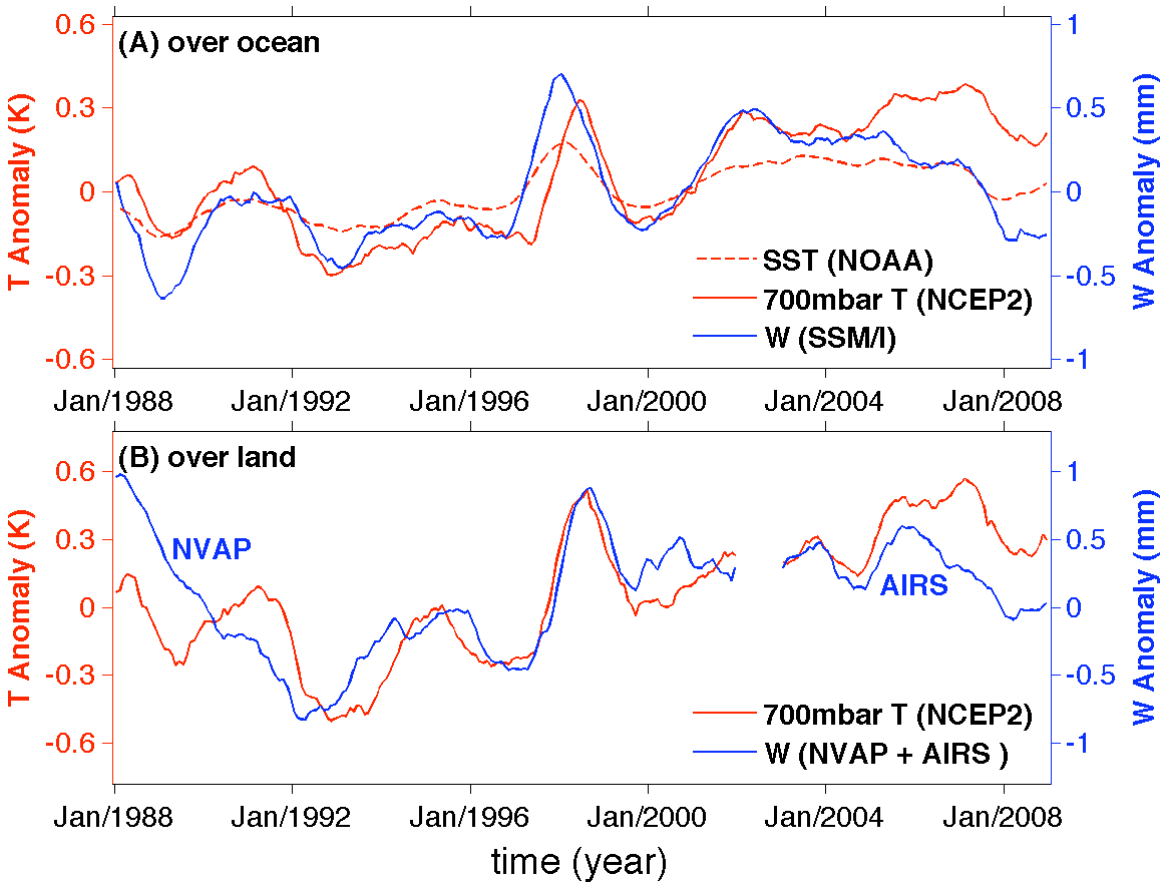
Examination with new version data sets (GPCP V2.1 and SSM/I V5)



	$\Delta P/\overline{P}$
GPCP V2	1.3±0.6%/decade
GPCP V2.1	0.3±0.5%/decade
GPCP V2.1 + SSM/I V5	- 0.3±0.6%/decade

$\Delta R/\overline{R}$? 0 or ε ? 1

Water Vapor (W)



Correlation of T and W

Ocean: **SST & W 0.72**

700-mbar T & W 0.61

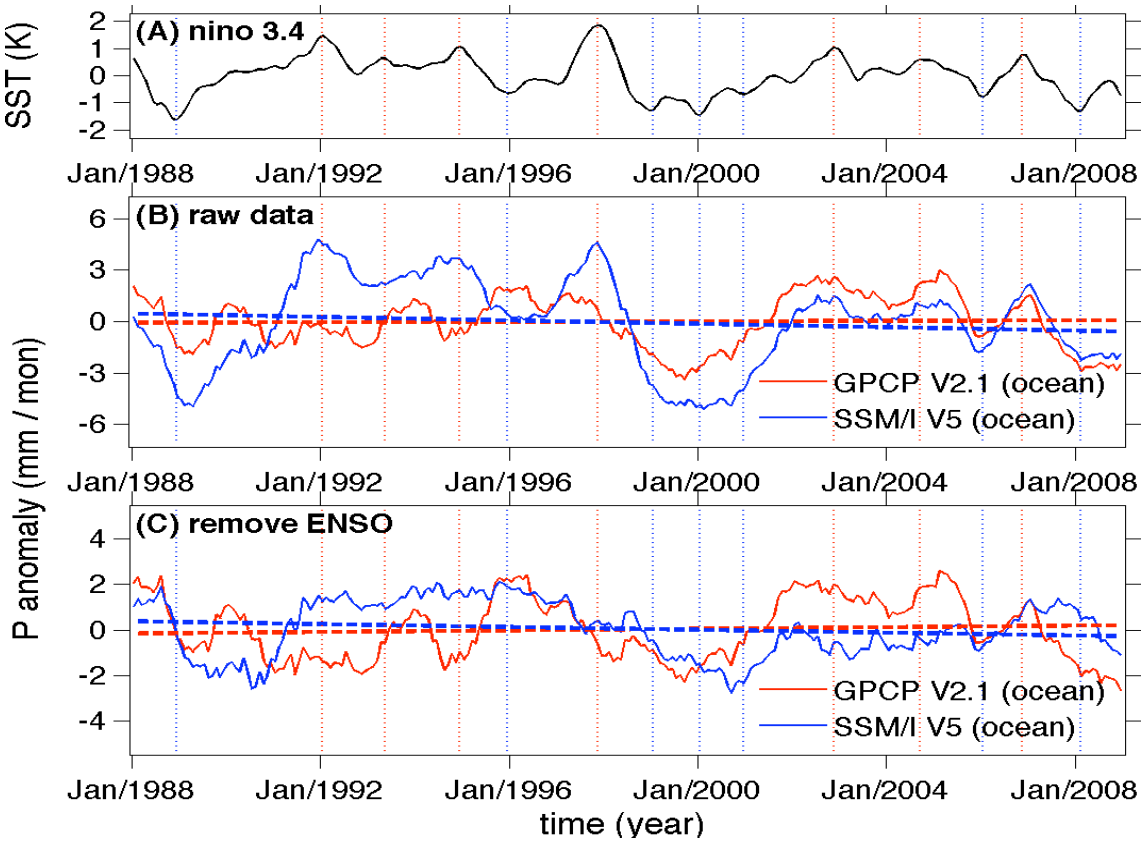
Land: 700-mbar T & W 0.55

*** Correlation over ocean > Correlation over land (Clausius-Claperyron law).**

*** Lack of long-term continuous water vapor (W) over land make it hard to estimate recycling rate (R) over the whole globe (ocean and land).**

Precipitation Over Ocean

* High-quality data sets over ocean between 60°N and 60°S.
* Coast regions are excluded from this study.



Nino 3.4 Index

Raw Data

GPCP V2.1
0.07±0.7%/decade

SSM/I V5
-0.6±1.5%/decade

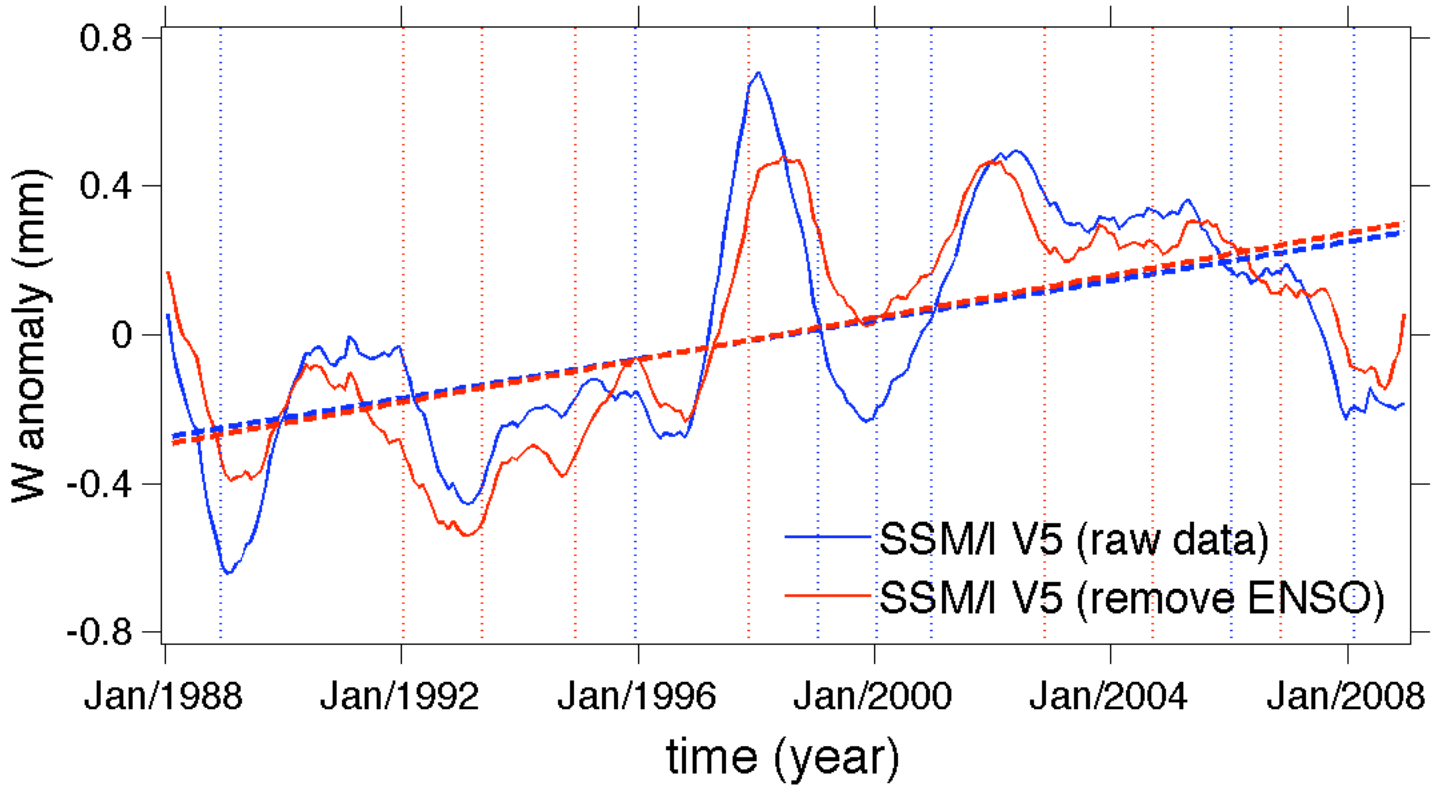
Removing ENSO

GPCP V2.1
0.13±0.6%/decade

SSM/I V5
-0.4±0.9%/decade

* Precipitation is correlated with ENSO signals.
* No significant trend in ocean-average precipitation during 1988-2008.

Water Vapor Over Ocean

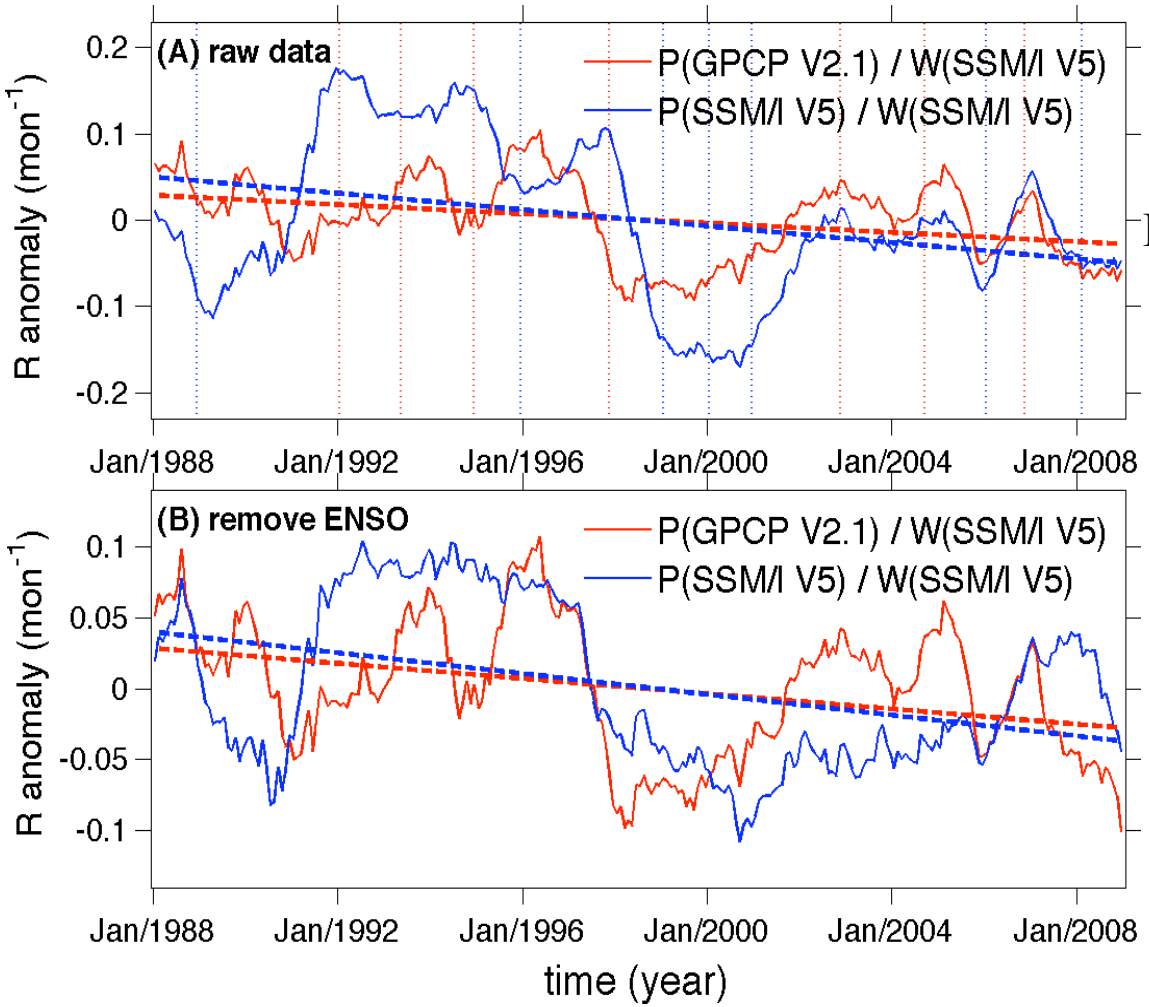


Water vapor trend over ocean

raw data	**0.9±0.5%/decade**
remove ENSO	**1.0±0.4%/decade**

*** A positive trend in ocean-average water vapor during 1988-2008.**
($0.3 kg/m^2$ per decade , roughly same as $0.4 kg/m^2$ per decade during 1988-2006 (Santer et al., 2007)).

Recycling Rate Over Ocean



Trend of Recycling Rate (R)

Raw Data

P (GPCP) / W (SSM/I)
-0.9±0.7%/decade

P (SSM/I) / W (SSM/I)
-1.4±1.3%/decade

Removing ENSO

P (GPCP) / W (SSM/I)
-0.9±0.6%/decade

P (SSM/I) / W (SSM/I)
-1.2±0.9%/decade

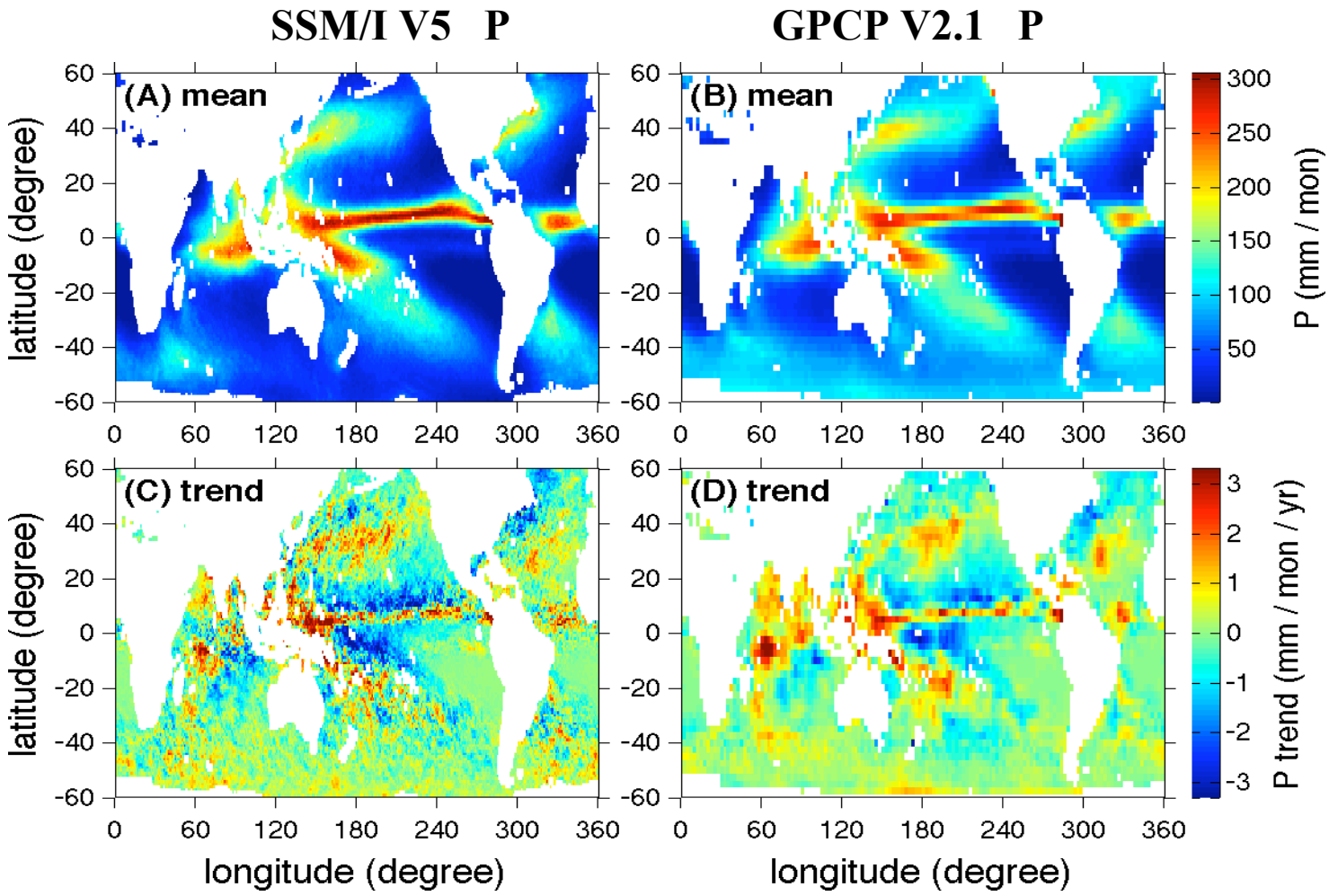
*** A weak negative trend in ocean-average recycling rate, which means:**

$$\Delta R / \overline{R} \; < \; 0$$

Spatial Pattern (Precipitation)

Time-mean State

Linear Trend



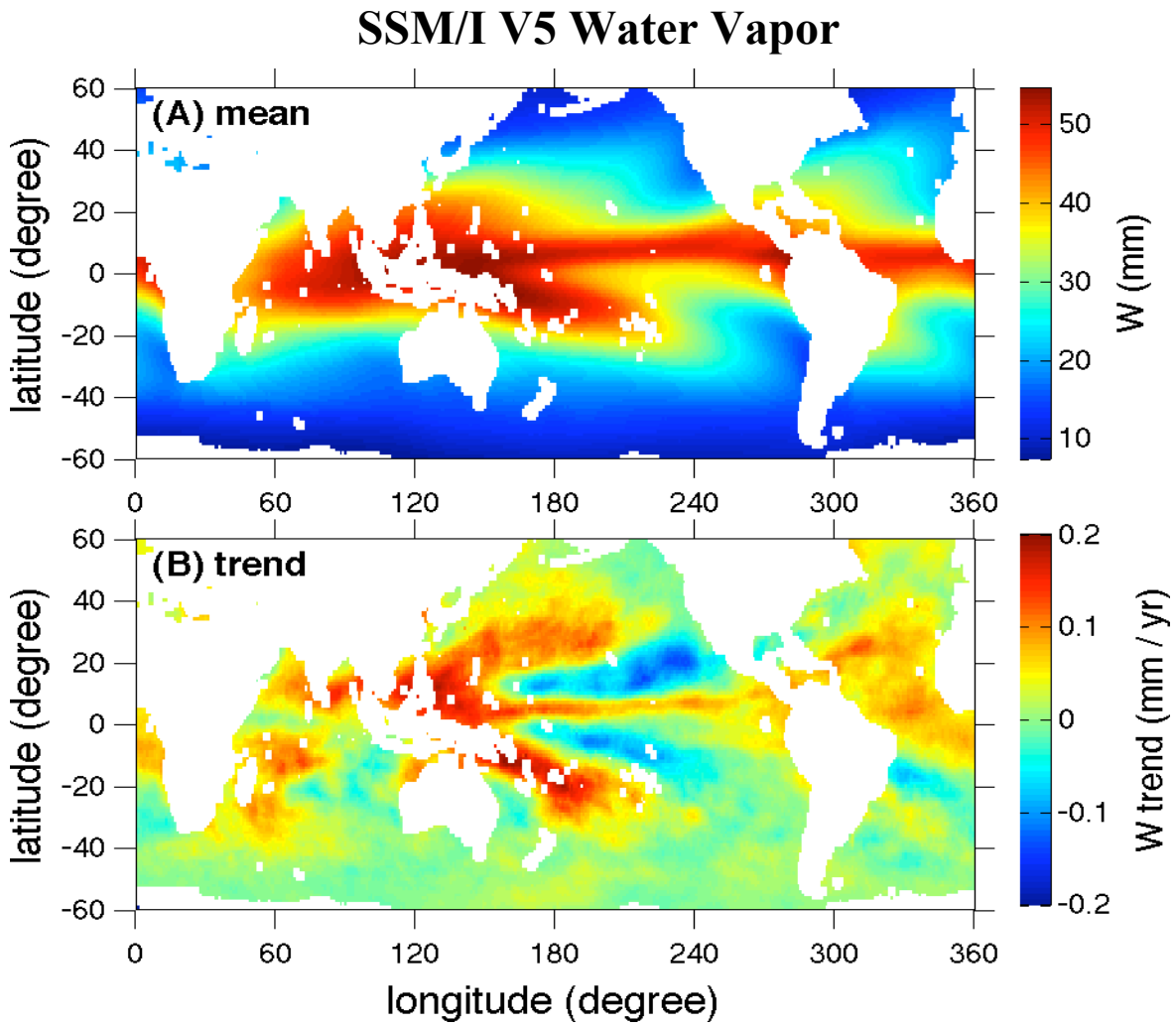
*** Positive trend in strong precipitation regions (ITCZ).**

*** Negative trend in some weak precipitation regions.**

Spatial Pattern (Water Vapor)

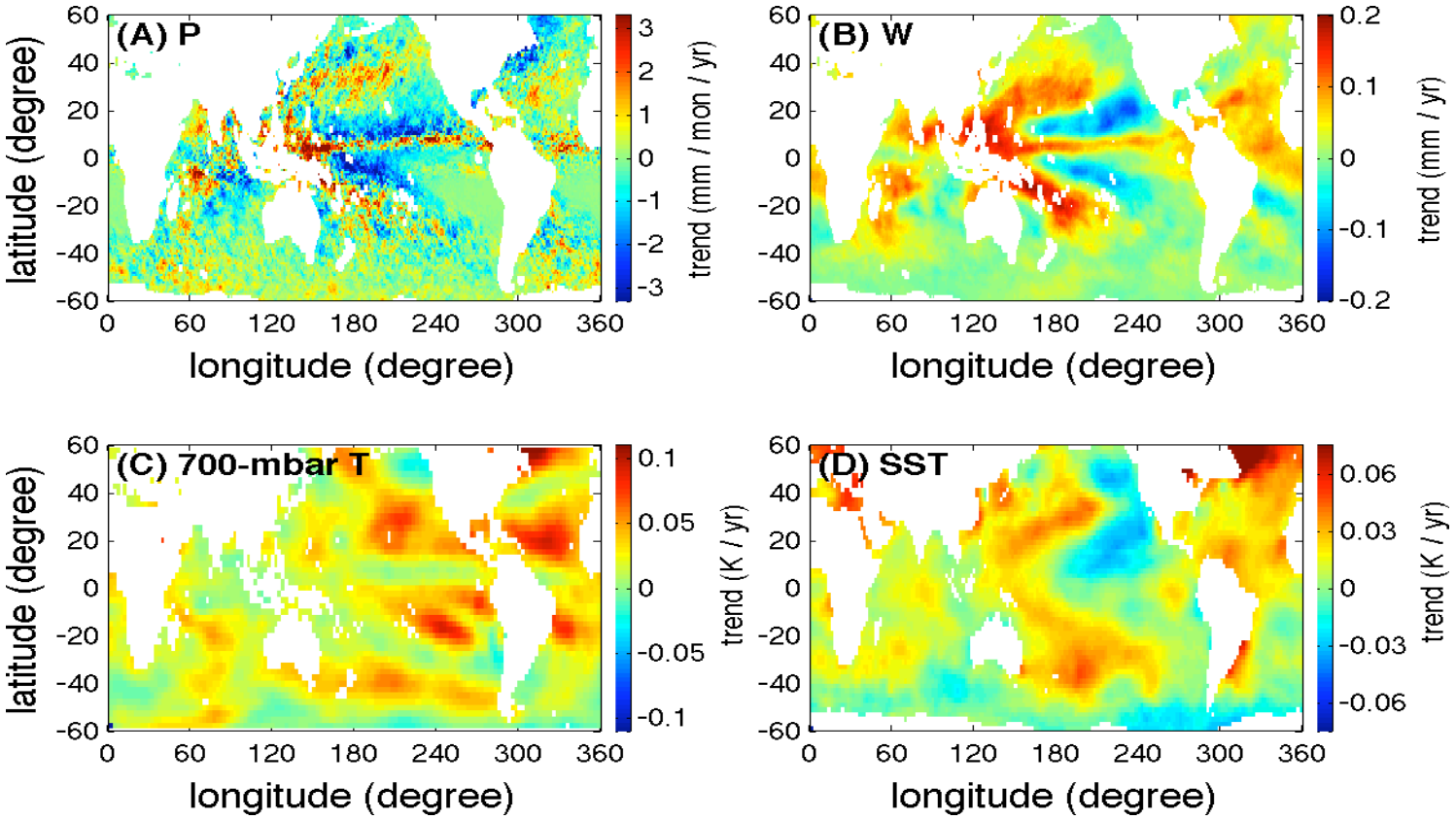
Time-mean State

Linear Trend



Spatial Pattern (Trend Comparison)

(A) Precipitation trend; (B) Water Vapor trend;
(C) Atmospheric temperature trend; (D) SST trend.



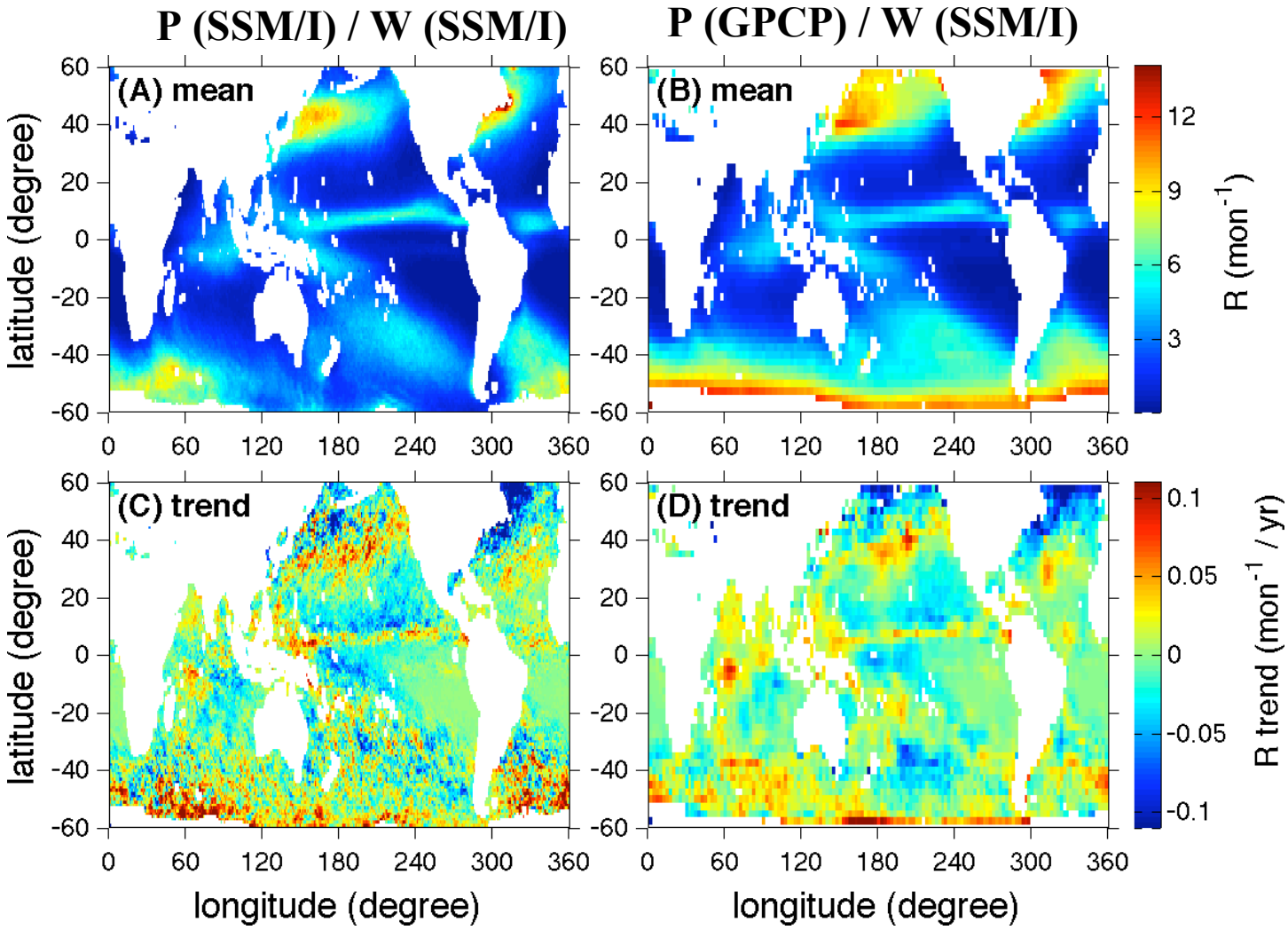
*** Trends in precipitation and water vapor have roughly same spatial patterns.**

*** Comparing with atmospheric temperature, SST trend pattern is more close to P/W.**

Spatial Pattern (Recycling Rate)

Time-mean State

Linear Trend

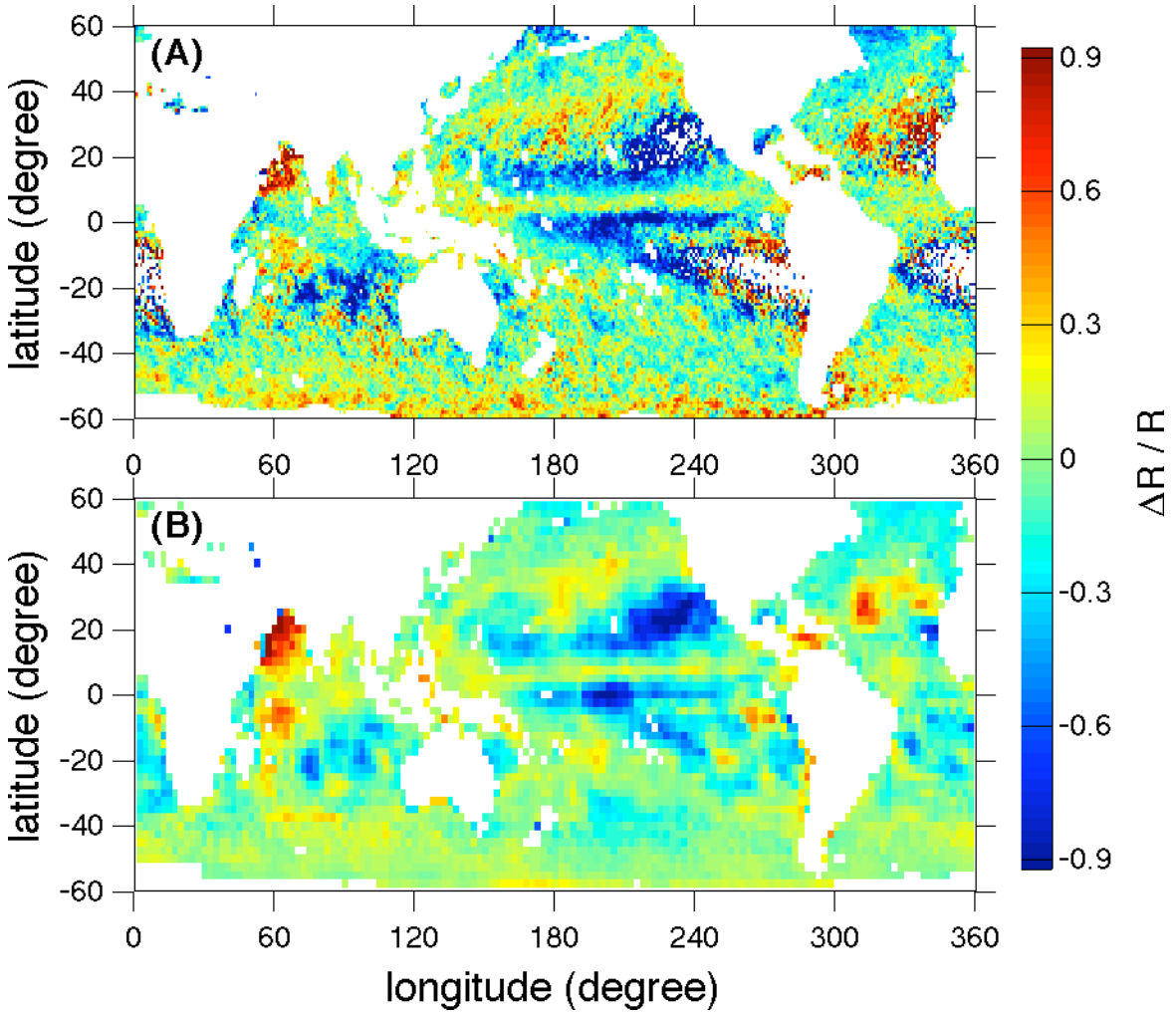


*** Positive trend in high recycling-rate areas over tropical ocean (ITCZ).**

Spatial Pattern (Recycling Rate)

ΔR/R from
P (SSM/I) & W (SSM/I)

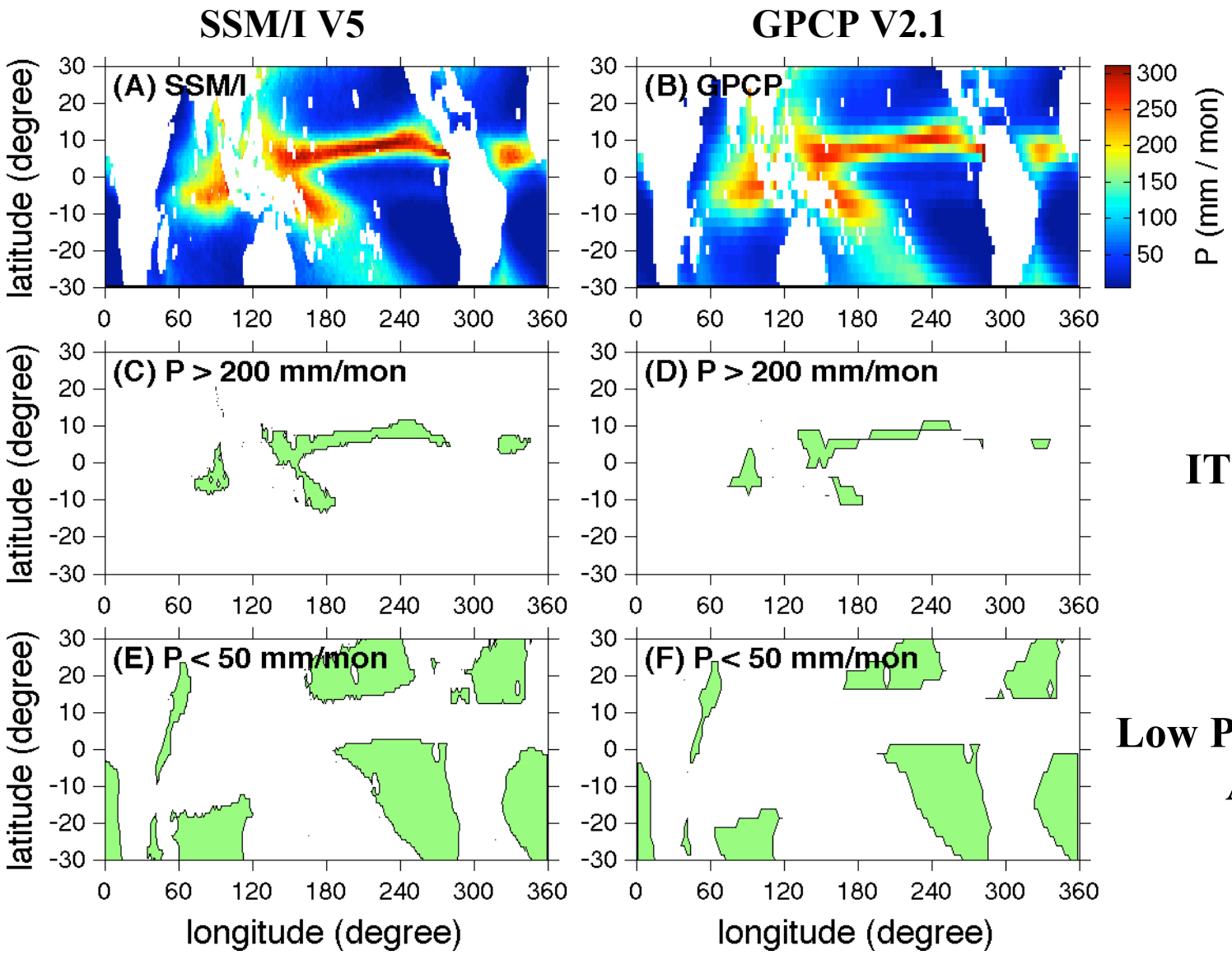
ΔR/R from
P (GPCP) & W (SSM/I)



*** Ocean-Average:** $\Delta R/\overline{R} < 0$

***However, for ITCZ area:** $\Delta R/\overline{R} > 0$

ITCZ Area (Definition)

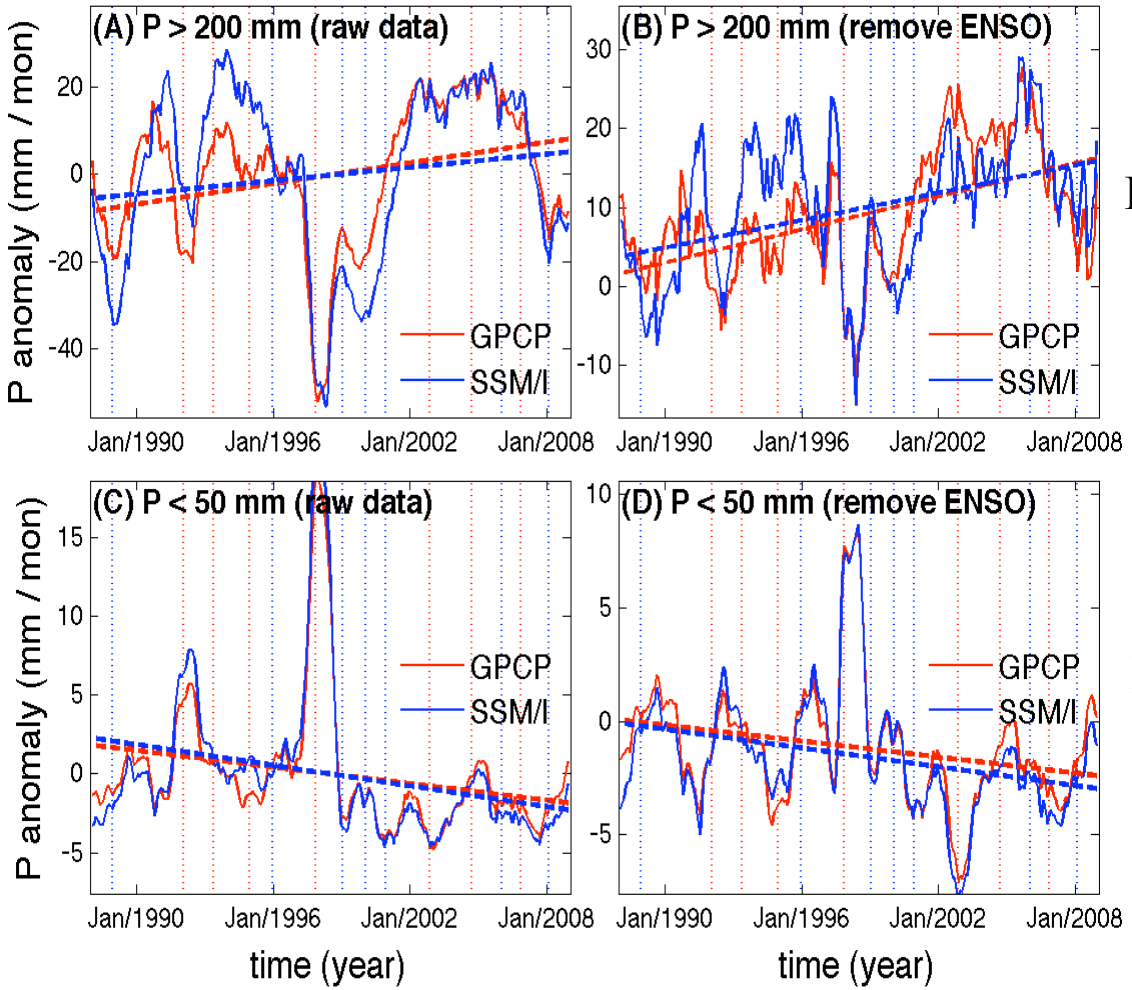


ITCZ

Low Precipitation Area

ITCZ Area (Precipitation)

Raw Data **Removing ENSO** **Precipitation Trend**



ITCZ area:

GPCP V2.1
3.1±1.5%/decade

SSM/I V5
2.5±1.6%/decade

Low-P area:

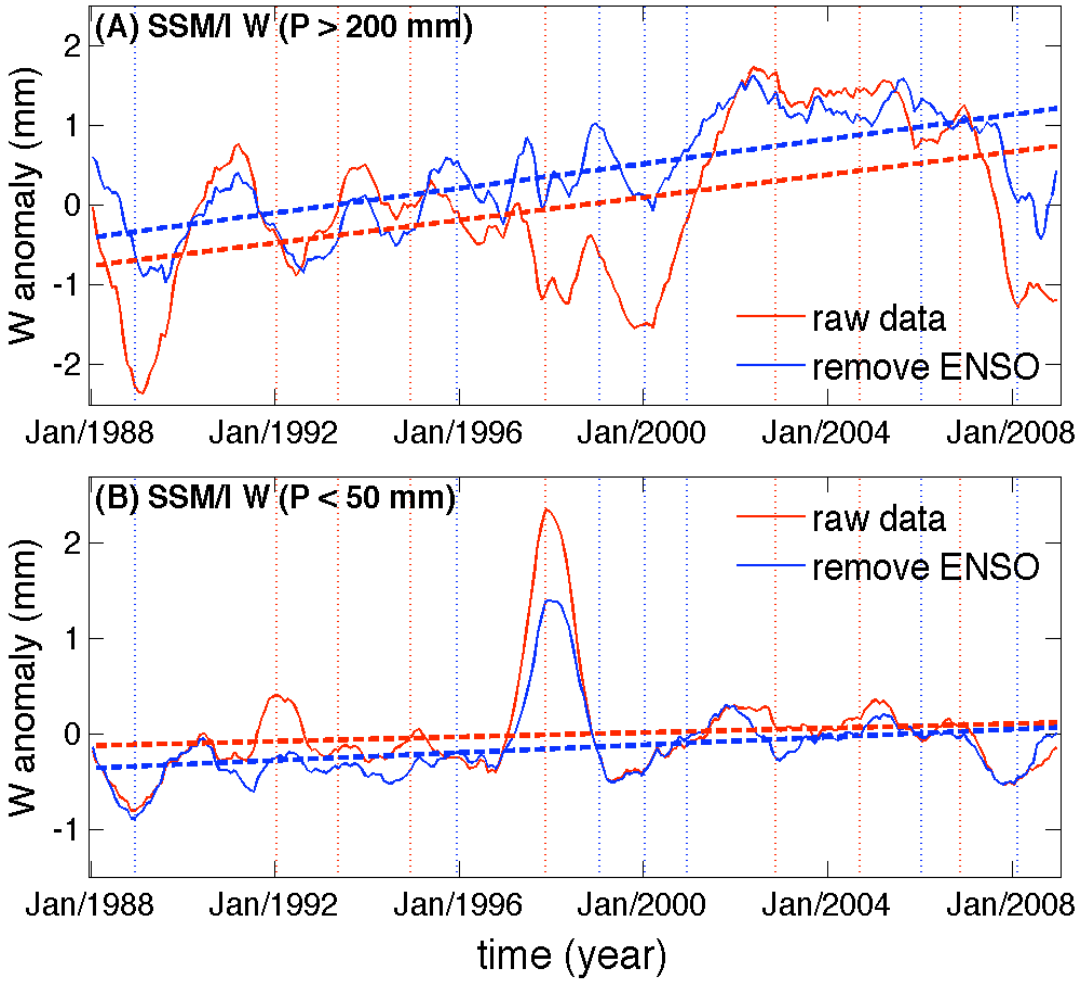
GPCP V2.1
-6.5±4.5%/decade

SSM/I V5
-7.7±5.6%/decade

*** Strong El Nino (97-98) critically affects precipitation.**

*** Positive precipitation trend in ITCZ; Negative trend in low-P area.**

ITCZ Area (Water Vapor)



Water Vapor Trend

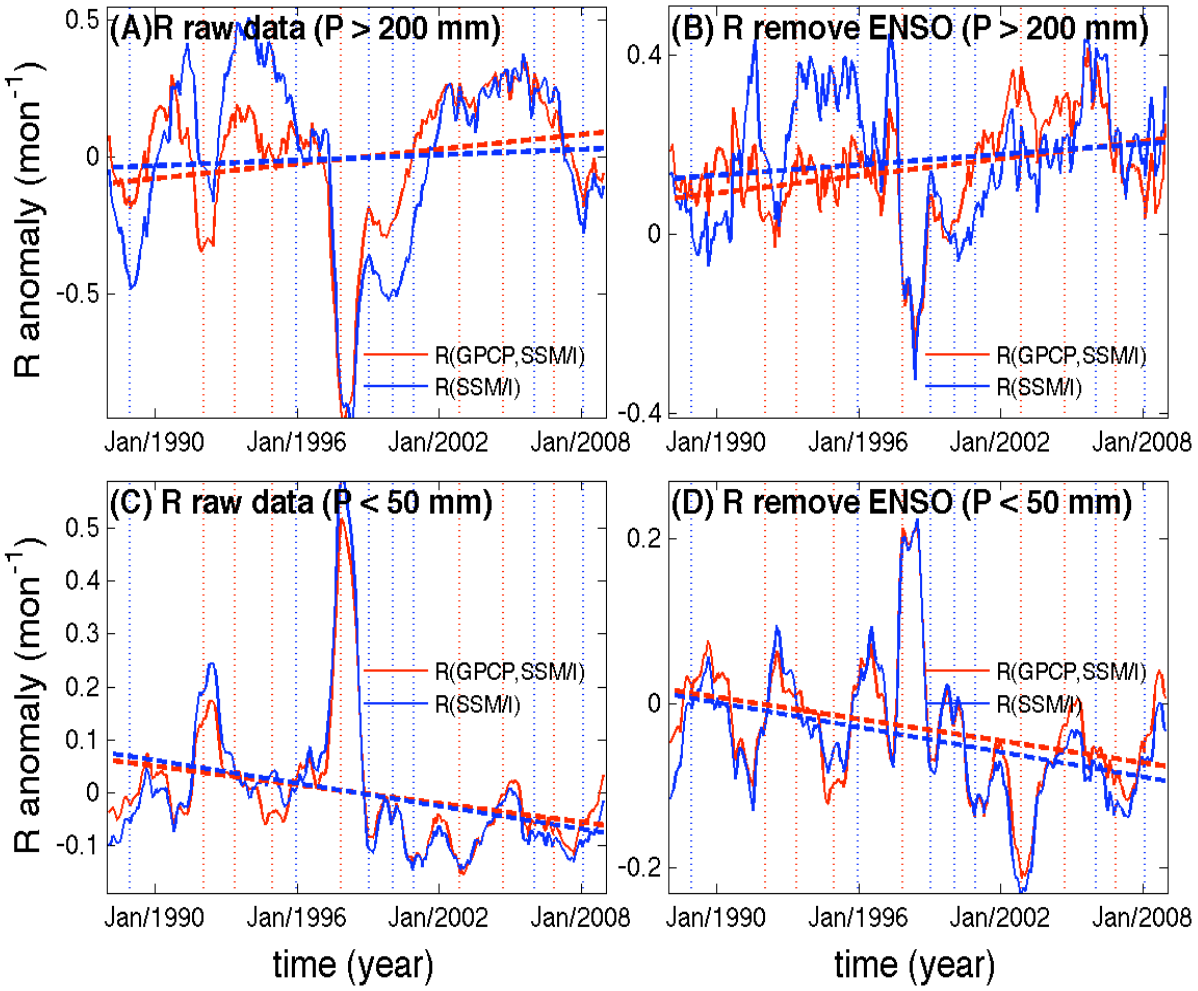
ITCZ: **1.5±0.6%/decade**

Low-P area: **0.6±0.6%/decade**

*** Positive water-vapor trend in ITCZ area.**

*** Strong El Nino events (i.e., 1997-98) affects water vapor in low-P areas.**

ITCZ Area (Recycling Rate)



Recycling Rate Trend

ITCZ area:

P(GPCP)/W(SSM/I)
1.7±1.1%/decade

P(SSM/I)/W(SSM/I)
0.8±1.3%/decade

Low-P area:

P(GPCP)/W(SSM/I)
-5.8±3.5%/decade

P(SSM/I)/W(SSM/I)
-8.7±5.1%/decade

*** Weak positive recycling-rate trend in ITCZ area and negative trend in low-P area.**

*** Strong El Nino (i.e., 1997-98) affects tropical recycling rate.**

Conclusions

- New Precipitation (P) data suggest a much weaker trend.
  Lack of long-term continuous water-vapor (W) data over land make it hard to estimate global recycling rate.

- Over the ocean, consistence between GPCP V2.1 and SSM/I V5 suggests a negative trend in spatial-average recycling rate (R).

- However, positive trends of P, W, and R are detected in high-P area (ITCZ), and negative trends of P and R are detected in low-P area. ***It suggests that extreme weather intensified along global warming during the past two decades.***

- Strong El Nino (i.e., 1997-98) critically modify hydrological cycle over tropical region (need more observations).

Acknowledgement

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